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A DISCUSSION OF DYNAMIC CRACK

PROPAGATION IN BENT PLATES

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A major goal of the hydraulic ram technology program for aircraft fuel tanks is the development of analytical - numerical tools for the accurate prediction of damage to the tank due to a ballistic projectile. This report discusses the problem of cracking of the tank walls due to hydraulic ram pressures from the penetrating projectile. A bibliography of studies on dynamic crack propagation in transversely deflected thin plates is presented.

A major goal of the hydraulic ram technology program is the development of analytical-numerical tools for the accurate prediction of the damage incurred by an aircraft fuel tank when hit by a ballistic projectile. Tests and simplified analyses have shown that the walls of the fuel tank where the bullet enters and where it exits may suffer severe cracking and petalling. This cracking and petalling is caused by the intense loading on the wall due to the passage of the bullet through the fluid. High speed photography has shown that the exit wall may crack prior to penetration by the projectile. These films also show that severe cracking of the exit wall occurs relatively early in the response time period. Similar results of early cracking have been documented for entry wall cracking due to penetration into fluid filled tanks by high speed spherical projectiles i.e., the meteoroid problem in outer space.

A somewhat related dynamic cracking situation is the empirical explosion bulge test, which is a NAVSHIPS standard procedure for preproduction testing of materials. Briefly, this test consists of bulging a test plate into a die with a circular cutout using an explosive charge. The tests are run at various temperatures to determine the temperature at which a crack is initiated but is arrested when it reaches the elastic hold-down region of the plate, and the temperature at which the plate shatters with very little overall plastic deformation. The explosive charge and standoff distance are such that a 3-5% thinning of the plate is produced at a temperature at least 60° F above the temperature at which the plate shatters.

At the present time, very little experimental or analytical detailed information is available regarding the progressive dynamic cracking of a plate subjected to a transient normal pressure. It appears that no theory or computer tool has yet been formulated that will predict the cracking of the transiently loaded plate as a function of time.* The complications involved in the cracking process are many. Among them are:

1) a three dimensional stress state
2) transient conditions
3) large geometry changes
4) a change in the stress distribution throughout the plate due to cracking.

The theory requires a criterion for crack initiation and propagation in bent plates, inclusion of strain rate effects, and consideration of material yielding and shear and cleavage fractures.

There are many books, reports, and papers devoted to the subject of fracture of metals and the behavior of metals under impulsive load. These books and papers usually devote many pages to the individual problems mentioned above, but it appears that no one has yet considered the total problem of interest here. A list of some of the appropriate books, reports, and papers is attached.

Our problem can be formulated in the following way. First, the loading on the wall and the elastic response of the wall prior to yielding and cracking must be determined. This provides a transient stress state. Comparing this state with a yield condition will determine if yielding occurs.

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*There is a computer code available called CRACKS. This code predicts the crack propagation in cyclic loaded structures. It is applicable to oscillatory loading conditions such as those due to unbalanced machinery or engines, and certain flight conditions. It is not applicable to the problem under consideration here of a single, intense loading condition.

If it does, this must be taken into account in the subsequent response computations. (The Northrup Code BR-1 does this.) A flow rule relating stress and elastic and inelastic strain, or their increments, must be selected. As the response continues in time it must be compared to a fracture criterion. If fracture occurs, the structure has been changed, and this must be taken into account in the subsequent response computations since the cracks will affect the stress distribution in the plate.* The conditions for crack propagation must be examined to see if the cracks will continue to propagate. Large geometry changes will occur if the wall starts to petal outward. This affects the loading on the wall. The problem is further complicated by the penetration of the projectile through the wall.

Our approach to the solution to this problem is to develop a computer code, or modify an existing one such as the BR-1 code, that can be used to predict the initiation and propagation of cracks in a plate loaded by a transient normal pressure. The code will use either finite elements, or finite differences, or a combination of the two to compute the transient stress distribution. A theory of crack initiation and propagation will be selected from the current theories**, and incorporated into the code. Tests on blast loaded plates will be conducted at NWC to obtain experimental data to be compared with the analytical predictions.

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*With regard to the computation of the changed stress distribution due to the crack, the finite element method has recently been used to predict the stress field in the vicinity of cracks.

**A promising theory is the one proposed by SRI in "Dynamic Fracture Criteria of Homogeneous Materials," by Barbee, T., Seaman, L., and Crewdson, R., AFWL-TR-72-99, November 1970.

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